

Dr. Achilleas Xydis







design

and the second

Absorption reduce sound levels lowen reverberation time

Diffusion reduce flutter echoes reduce image shifts maintain sound energy



101

1.1 3 2 4 ..

Elbphilharmonie Hamburg - Großer Saal

-



AN AN AN



FUZ Offices - TURF Design

T

I AH

111

TA





Schlieren photography





Osswald, Franz Max

Physical scale modelling

Computer simulations



Physical scale modelling



1:10 physical scale model of the La Philharmonie de Paris. © Nicolas Bore

Exterior view of the 1:10 physical scale model of the La Philharmonie de Paris. © Nicolas Borel











Wave-based modelling

Geometrical Acoustics





+ Accurate results

- Slow
- Not suitable for high frequencies
 Dense discretisation → computationally expensive
- Not suitable for large spaces
 Large number of points → computationally expensive



FDTD simulation - Dr. Kurt Heutschi, EMPA





+ Fast

- Less accurate
 Sound is assumed to be a ray
- Requires a Low Level of Detail model Geometric acoustics assumption not valid otherwise
- Not suitable for low frequencies
 Assumption not valid otherwise
- Standardised material properties Absorption / Scattering coefficients



Ray tracing – Odeon.dk



Computer simulations





Computer simulations







"...the process of rendering audible, by physical or mathematical modelling, the sound field of a source in a space."

Kleiner, Mendel, Bengt-Inge Dalenbäck, and Peter Svensson. "Auralization-an overview." Journal of the Audio Engineering Society 41, no. 11 (1993): 861-875.



Sound perception

Acoustical descriptors vs Intuitive Immersive applications





Room Impulse Response

Amplitude Frequency response Reverberation time

Dependent on source-receiver position

Anechoic sound file





Output

Mono

Stereo

Binaural





Ear shape











Shoulder/torso reflections





Frequency response



How it works binaural

Dummy Heads



KEMAR, Brüel & Kjær 4128 HATS, Head Acoustics HMS III, and Neumann KU-100

How it works binaural

HRTF



Bruschi et. al. 2024. "A Review on Head-Related Transfer Function Generation for Spatial Audio" Applied Sciences 14, no. 23

Output

Mono

Stereo

Binaural

Ambisonics

Ambisonics



Ambisonics

full-sphere surround sound format speaker-independent sound field decoded to any speaker setup



Immersive Design Lab, ETH Zurich

